

**Vulnerability of the National Electric Grid to the Influences of Renewable
Power Generation and Consumption**

UNDERGRADUATE RESEARCH THESIS

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By
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Abstract

Trends over the past 25 years suggest a decline in fossil fuel consumption per capita and an increase in per capita consumption of renewable energies. Consumption per capita of energy generated from fossil fuels, as a percentage of the total per capita consumption, declined from 92.3% to 89.3%, while per capita consumption of renewables increased from 7.7% to 12.0%. Should these trends persist, the utilities sector could be in danger of decreased profits, which could lead to cost cutting measures and ultimately a lessening of maintenance for the national electric grid in the distant future. A multiple linear regression model was created to forecast the future affect that a switch in energy consumption would have on the utilities sector in the United States and the price sensitivity in different sectors. The model utilizes annual renewable energy consumption per capita and sector-based electricity pricing to predict the annual consumption of fossil fuels per capita. Forecasts for fossil fuel consumption per capita could show how the current landscape of the utilities sector, which generates power largely from fossil fuels, will be troubled, should sector strategies not adapt. Based off of the predictive model, should current trends persist, the utilities sector will see decreasing profits. To counteract lower profits, electricity prices may increase to some customers, potentially causing consumers to search for alternate sources of electricity. Though not an immediate threat due to its small share of the energy market, renewable energy trends suggest that consumer's source of energy will shift in the future, from fossil fuels to renewables. Additionally, changes in regulation throughout the industry could alter the energy landscape further. Without a change to the current

structure of the utilities sector, and if facilitated by regulatory alterations, customers could increasingly leave the national electric grid in favor of lower cost alternatives.

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Introduction

The Problem

Past energy generation and consumption have been defined by fossil fuels. Until the past few decades, fossil fuel generation was the only means by which the residential, commercial, industrial, and transportation sectors were able to receive energy. Large power plants burned coal, oil, and natural gas to heat large water reserves that would in turn generate steam. Steam was then pumped into turbines to create electricity. The newly generated energy would then be pumped into the national electric grid and distributed to businesses and households around the country.

In the recent past, renewable sources of energy have slowly been gaining ground against fossil fuels, now accounting for about 10 percent of the energy market (“Independent . . . Analysis”). Combined with government regulation, renewable energy sources are being positioned to become a potential threat to fossil fuels and energy derived from these sources in the distant future.

The intention of this research is to examine recent trends in per capita energy consumption of fossil fuels and renewable sources and the price paid by different end user segments. A predictive model is built using historical data. This model is used to analyze the price sensitivity of different end user segments of the energy market as well as the aggregate market. The model allows us to forecast the future landscape of the industry and provides insight into the need for industry restructuring to maintain current levels of profitability in a changing energy environment.

Background

Energy Usage in the Past

Since the turn of the century, the energy sector has received a large amount of publicity as people and corporations search for methods to handle the increase in demand for energy and electricity. Historically, the national electric grid is mainly fed electricity by large power plants burning fossil fuels, such as coal and natural gas. These power plants are owned and operated by the utility companies that profit by providing electricity to houses and businesses connected to the national power grid, which consists of almost every household and place of business in the United States. In the past, households would draw all of their electrical needs from the national power grid and then pay the utility company for generating and distributing the electricity.

Fossil fuels served as an increasingly expensive, until recently, source of energy that had been the focus of many global warming concerns. As the world became more focused on the lasting impact of depleting the world of its fossil fuels and faced with high prices, a small fraction of people began to turn to other sources of energy, which displayed renewable characteristics. Additionally, the movement to cleaner sources of energy has been occurring for many years, which has allowed for the utilization and growth of such sources as solar, wind, geothermal, biomass, and hydro among others.

Renewable Energy

Renewable sources of energy have been gaining ground for a number of years, with many states increasing their renewable energy generation. However, the amount of renewable energy consumed remains small compared to fossil fuel consumption, with renewable energy making up 10.6% of the market for consumed energy (“Independent . . . Analysis”). Some countries around the world, including Germany and Spain, have increased their renewable energy infrastructure, installing large wind farms and solar farms, respectively. In the United States, consumption has increased over the past decade, but has begun to level off in the last few years. Even with the leveling off of consumption, renewable energy generation has continued to increase. By 2014, wind power generation had increased by a little more than 2,598% over the wind power generation of 2001. Additionally, solar power generation had increased even more over 2001’s generation statistics, with a factor of a little more than 3,275% (“Independent . . . Analysis”). Wind generation gradually increased throughout the span of time between 2001 and 2014, whereas solar generation exponentially increased during the period of 2011 to 2014.

Distributed Energy

Individualized power generation or distributed power generation is a major threat to the national power grid. Rooftop solar panels and wind turbines on residential and commercial properties could pose a threat to the national electric grid and to the utility companies operating the electric grid. Renewable energy generation at the household level could potentially pose a threat to the current

national electric grid and how it operates. Recently, this dynamic is experiencing a dramatic change.

Households and businesses have been installing equipment that allows for the generation of power using wind, the sun, or other sources of natural power. People have begun to put wind turbines onto their property or solar panels onto their roofs to generate electricity and power their household or business. Without the use of batteries or some other storage device, the energy produced must be used immediately or sold back to the national electric grid. Because most of these locations that are producing their own energy are connected to the national electric grid, the excess energy generated by a household or business can be sent into the electric grid and redistributed to other households or neighbors. When the electricity generated by a household is put into the electric grid, the utility company must pay the household for the electricity being given to the company, even if the input is not necessary for current consumption or demand, thus posing a challenge to the utility companies.

Currently, the national energy grid is vulnerable to distributed energy, miniature grids, and smart grids (Randall). Distributed energy is gaining a large amount of momentum around the world as users are installing rooftop solar panels, wind turbines, and other energy generating equipment on their property. As a sign that distributed energy will continue to become a threat to national grids and conventional methods of distributing power around the world, one of Germany's largest utility companies, E. ON, announced recently that it would be splitting its company. One company would continue to focus on the conventional methods of

power generation and distribution to Germany's electric grid, while the other company would focus mainly on the evolution into the distributed energy sector (Lacey). The company decided to move into the distributed energy market because the cost of technology in the renewable energy sector has continued to decline, with renewable energy costing around the same price as conventional energy generation, such as coal and natural gas. Additionally, with subsidies from the government of Germany, renewables are less expensive, which is pushing the price of coal and natural gas down. The decrease in prices of coal and natural gas is greatly hurting the business model and profits of the power plants that are supplying the grid with electricity (Lacey). E.ON's actions show a worldwide shift away from the conventional methods of power generation toward distributed energy and renewable technology.

Distributed energy also poses numerous advantages over conventional sources of energy and the national grid. Distributed energy maintains relatively low barriers to entry in the energy sector. The barriers to entry for a utility company with power plants that feed the national electric grid are extremely high, which reduces the competition in the sector (Weidman). Some small households are able to generate energy by purchasing affordable solar panels, which replaces energy created by power plants with high startup and maintenance costs. Additionally, there are many companies within the renewable energy sector that produce power generation equipment. Because the sales are made directly to the consumer, there are many sellers and buyers in the space, which increases the amount of competition and decreases the price of the equipment (Weidman). The competition

in this field also leads to great strides of innovation for the technology. The national electric grid is fairly mature and has not seen much innovation in the recent past as there are very few utility companies in the space caused by the high barriers to entry. The few, large firms that make up the utility sector do not need to compete with each other, thus the lack of competition in the sector leads to a lack of innovation. Lastly, much of the distributed technology is created using an assembly line process. Because of the assembly line process, the equipment can be made cheaply and efficiently, thus leading to a continual decrease in the price of distributed energy equipment (Weidman). This decrease in manufacturing costs could lead to a decrease in the cost of the equipment and a decrease in the cost of power generation. With lower costs to generate power from one's home, there could, theoretically, be less demand for power generated using power plants and distributed to households from the national grid. This lowering in cost of technology could eventually pose a threat to the current electric grid. If this trend continues to increase, then utilities are "heading for extinction as we all go off the grid" (Weidman).

Miniature grids and smart grids are another area that could pose a threat to the national electric grid. Mini grids are electric grids that are localized, thus they do not receive their supply of power from a large power plant. Rather, mini grids are meant to service a neighborhood or small community and be powered by either the homes or offices in community or by a localized power generation source, such as a large wind turbine. The households in an area would power the community and the energy would be shared among neighbors, thus eliminating most of the need for the

national electric grid. Another threat to the national power grid would be the innovation of smart grid technologies. Smart grids work to create a more efficient grid by implementing the use of data in the distribution of energy. Smart grids and mini grids have gained popularity, as they are methods to decrease the occurrence of blackouts and power outages.

The national electric grid is prone to power outages and blackouts in the face of weather events and natural disasters. Recently, there has been a stark increase in the frequency of natural disasters, catastrophes, and weather-related events (Jones). Because of the increase in these occurrences, the number of weather-related power outages has also increased. Because mini grids and smart grids cover a much smaller area than the national electric grid, power outages typically last a much shorter time and are handled much more rapidly than outages of the national electric grid.

One of the sources of renewable energy that is garnering publicity as a potential threat to the national electric grid in the somewhat distant future is solar power. Some argue solar power is disruptive to the national electric grid because people who use solar energy are not utilizing the energy that comes from their connection to the electric grid, thus they are basically detached from the electric grid. A lessening in demand for energy from the electric grid, thereby a lessening in demand of energy from utility companies will effectively drive up prices of energy for those users that continue to use the electric grid as a source of energy. In relation to energy distributed through the electric grid, solar energy generation will become relatively cheaper and more appealing to the user. As more people move away from

energy generated by the utility company and toward solar energy generated off the grid, the earnings of the utility companies will continue to decline, leading to a vicious cycle of price increase and resulting customer loss (Gunther).

Over the past few years, solar energy has started to grow exponentially. In 2012, the amount of solar power that was generated accounted for less than one percent of the total power generated, with the actual number being close to 0.11% of the total output generated (Gunther). In September of 2013, an article was published which stated that “solar is now ‘in the market’ for 16 percent of U.S. retail electricity sales” (Weidman). The same article stated that the percentage could double by 2017, with solar competing for a larger market share of the \$170 billion industry (Weidman). Additionally, in 2012, 90,000 households installed rooftop solar panels into their homes, which generates output in the equivalent of a large power plant (Gunther). With the increase in market share of solar power generation and the increase in installations, solar power is beginning to make large strides in growth. The chairman of the Federal Energy Regulatory Commission, Jon Wellinghoff was quoted saying that “solar could double every two years” (Gunther). Should solar actually double every two years, the utility companies will begin to face growing hardships as they fight to maintain profitability. The growth in the solar energy sector is also boosted by falling prices of solar power generation.

The cost of equipment used to generate solar power has greatly declined throughout the recent past. In 2012, the average price of solar power generation decreased by a factor of 26.6% over 2011. The cost of a solar module, used to generate power from solar, by 2012, had decreased to a level that was one percent

of the price 35 years ago (Lacey). The technology used to harness the power of the sun has dramatically decreased in price as there are many companies creating their version of the technology. From 2010 to 2014, the price of an installed solar power generation unit had declined by about 63% (“Solar . . . Figures”). The large amount of production and innovation in the field has created a surplus of solar technology, thus reducing the price of the technology even further. Additionally, the price of renewable technology is being offset by the ability to sell excess energy generated to the utility companies through the electric grid. When it is a sunny day and a household is producing more energy than they need at the given moment, the unused energy will be sent back into the electric grid and redistributed into a household without excess energy. The utility company buys the energy sent into the grid from the household at market rates, which are currently about 10-12 cents per kilowatt-hour (Gunther). Even if the utility company is producing enough energy for all households in a given sector of the grid, the company must purchase the excess energy. Often, the energy they must purchase costs about 75% more than other sources of energy they could be utilizing, thus eating further into the earnings of the utility companies (Gunther). With declining prices and the ability to sell excess energy to utility companies, solar technology is becoming more appealing to users and more threatening to the electric grid and the utility companies. As a result of the declining prices of solar technology, the capacity of solar power has greatly increased.

In 2014, solar technology accounted for 36% of new energy capacity in the United States. Projections into 2015 and 2016 suggest that solar installations will

continue to grow in multitude and magnitude, with projected installation capacity in 2016 expected to exceed 12,000 megawatts of energy (“Solar . . . Figures”). Even though still small compared to energy generated through fossil fuels, total capacity continues to increase as the number of installations in the United States grows. As of 2014, the total capacity of solar electricity had reached 20 gigawatts of electricity. Projections suggest that the total capacity in the United States could double by the end of 2016 (“Solar . . . Figures”). This increased capacity comes at the same time as a decline in the consumption of fossil fuel sources. In the past few years, consumption of coal and natural gas has slightly declined, with decreases of -1.10% and -1.41%, respectively from 2013 to 2014 (“Independent . . . Analysis”). Over the same span of time, however, net generation of power in the United States has stayed relatively consistent (“Independent . . . Analysis”). With net generation staying constant and fossil fuel consumption decreasing, the data suggests that the market share of electricity generation and distribution is slowly and gradually moving away from the large power plants that burn fossil fuels to supply the electric grid and more toward renewable energy sources that can generate power without the use of large power plants. Maybe not in the near future, but without any change to the way in which the national electric grid is supplied, operated, and utilized, the grid could be vulnerable to the changing energy landscape.

For the purposes of this research, renewable energy and distributed energy are considered the same, thus the terms are used interchangeably.

Market Differentiation

The scenario being examined poses two separate markets for analysis. The markets consist of situations in which the utility company is the consumer and another where the utility company is the producer or supplier.

Utility as Consumer

One market that exists in this scenario consists of the utility company as the consumer. In this market, utility companies purchase fossil fuels or technology to harness renewable energy as a raw material. The utility company is the end-user in this market, which consists of consumption of fossil fuels and consumption of renewable energy by these companies. This market would not include the end user that consumes electricity generated by the utilities. The first predictive model (refer to Table 1) shown later, depicts the changes that could occur within this market, where utilities are the end-user.

Utility as Supplier

A second market in which the utilities operate is a market where the utility company is the supplier. In this market, utilities supply energy, in the form of electricity, to their customers, which are thus the end-users. This market also encompasses the renewable energy that is generated by the end-user, whether that be a residential end-user, commercial end-user, or industrial end-user. An analysis for the price sensitivity in each sector has been completed, with the models depicted in tables 2-5. A market where the utility company is the supplier maintains that the

customers of the utility company are the absolute end-user, thus utilizing the electricity that is delivered by the utility.

Variables

Numerous variables were analyzed in searching for the adequate predictors for the models discussed later. Consumption of fossil fuels, consumption of renewables, and electricity prices and sales to residential, commercial, and industrial end consumers were three factors that were believed to have an impact on the overall landscape of the utilities sector.

All data utilized throughout the following analyses is with regard to the United States only. Data does not reflect changes in and impact upon the energy industry of other countries, as international energy industries prove to be quite different from that of the United States. Data described in the subsequent variables was gathered and distributed by the U.S. Energy Information Administration, a branch of the U.S. Department of Energy.

Dependent Variables

Fossil Fuel Consumption per Capita

The utilities sector mainly utilizes fossil fuel when generating electricity in power plants, thus the consumption of fossil fuels throughout time seemed to be a good indicator of performance in the utilities sector. If consumption of a product created by the utilities sector (electricity created using fossil fuels) decreased, then it is expected that the revenue and profits of the utility would also decrease. Fossil

fuel consumption aggregated the major sources of energy generated using fossil fuels. The variable contains consumption of coal, natural gas, and oil/oil byproducts. Additionally, the consumption statistics were aggregated across the entirety of the United States. The sum of all consumption throughout the United States in one year was then converted from Btu (British Thermal Unit) to kWh (kilowatt-hours) at a conversion rate of 0.000293071 Btu to kWh to scale down the data. Lastly, the annual consumption data was normalized for the population in the corresponding year to account for growth in the United States population over time, as more people will naturally lead to an increase in the consumption of energy. After these manipulations, the result was a dependent variable defined as the annual fossil fuel consumption per capita expressed in kilowatt-hours (kWh).

Residential Electricity Sales

Sales to the residential sector reflects the amount of energy that is delivered and consumed by the residential end users in the United States. As a dependent variable, residential electricity sales provide insight into the possible effects that different variables will have on the amount of electricity consumed by residential end users in the future. Data on residential electricity sales entails the total quantity of electricity that was distributed to the residential sector per year, aggregated for the entire United States. The quantity of electricity that is expressed in this variable consists of electricity that is received by the end user from a utility company. The statistics consist of a summation of all electricity to this sector, expressed in megawatt-hours (MWh).

Commercial Electricity Sales

Sales to the commercial sector reflects the amount of energy that is delivered and consumed by the commercial end users in the United States. As a dependent variable, commercial electricity sales provide insight into the possible effects that different variables will have on the amount of electricity consumed by commercial end users in the future. Data on commercial electricity sales entails the total quantity of electricity that was distributed to the commercial sector per year, aggregated for the entire United States. The quantity of electricity that is expressed in this variable consists of electricity that is received by the end user from a utility company. The statistics consist of a summation of all electricity to this sector, expressed in megawatt-hours (MWh).

Industrial Electricity Sales

Sales to the industrial sector reflects the amount of energy that is delivered and consumed by the industrial end users in the United States. As a dependent variable, industrial electricity sales provide insight into the possible effects that different variables will have on the amount of electricity consumed by industrial end users in the future. Data on industrial electricity sales entails the total quantity of electricity that was distributed to the industrial sector per year, aggregated for the entire United States. The quantity of electricity that is expressed in this variable consists of electricity that is received by the end user from a utility company. The

statistics consist of a summation of all electricity to this sector, expressed in megawatt-hours (MWh).

Total Electricity Sales

Total electricity sales reflects the amount of energy that is delivered and consumed by all sectors (residential, commercial, and industrial) in the United States. As a dependent variable, total electricity sales provide insight into the possible effects that different variables will have on the amount of electricity consumed by end users in the United States, regardless of sector, in the future. Data on total electricity sales entails the total quantity of electricity that was distributed to end users per year, aggregated for the entire United States and across all markets. The quantity of electricity that is expressed in this variable consists of electricity that is received by the end user from a utility company. The statistics consist of a summation of all electricity, expressed in megawatt-hours (MWh).

Independent Variables

Renewable Energy Consumption per Capita

Renewable energy generation and consumption could pose a threat to the current utility industry, thus consumption of renewable energy is believed to be a strong predictor of future fossil fuel consumption. As discussed above, fossil fuel consumption trends could provide insights into how the utilities sector will fare financially in the future. If consumption of a competing product to the utilities sector

(electricity created using renewable energy) increased, then it would be expected that the income of the competitor (the utilities sector) would in turn decrease, as consumption of fossil fuel energy would decline. The variable accounts for renewable sources of energy less the effect of nuclear energy created. Nuclear energy was excluded due to its high barriers to entry and minimal accessibility to the general public. Most other sources of renewable energy are accessible to the general public for use in large and small-scale installations. Nuclear, however, is much more cost prohibitive and maintains a great amount regulation and risk for those involved. Renewable energy consumption, excluding nuclear, was aggregated across the entirety of the United States in the span of one year. The annual consumption data for renewable energy was again converted from Btu (British Thermal Unit) to kWh (kilowatt-hours) at a conversion rate of 0.000293071 Btu to kWh. Also like the variable of fossil fuel consumption, renewable energy consumption was normalized to account for population growth, as an increase in the population would lead to an increase in the amount of energy consumed. The resulting variable is annual renewable energy consumption (excluding nuclear energy) per capita expressed in kilowatt-hours (kWh).

Residential Electricity Prices

Residential electricity prices are believed to be a strong predictor of future sales of electricity to the residential sector, as it would be expected that if costs increased for residential end users, there would be a decrease in sales to the sector as customers search for cheaper alternatives to the electricity they are currently

utilizing from the utilities sector. As the utility companies are seeing their costs increase due to a decrease in the market share, the sector would need to increase prices in order to maintain the same level of profits as they had been generating before the introduction of renewable energy technologies. The variable of residential electricity prices aggregates all prices observed in the United States in one year. Electricity prices calculated based on the price charged for electricity purchased from utilities throughout the United States, thus the data does not include prices of electricity that are not received from the utility companies. Then the average price of electricity in the residential sector in that year is calculated. The variable represents the average price of electricity for residential consumers in the United States in the span of one year, expressed in cents (USD) per kilowatt-hour (kWh) of energy.

Commercial Electricity Prices

Commercial electricity prices are also believed to be a strong predictor of future sales of electricity to the commercial sector, following the same logic that was discussed with regards to residential electricity prices. Should the utilities sector see decreased profits, they may increase prices to reach a profitability similar to previous levels. Commercial end users should have a greater financial ability to seek alternate and cheaper sources of electricity than residential customers because of their scale in terms of size. The variable of commercial electricity prices aggregates all prices observed in the United States in one year. Electricity prices calculated based on the price charged for electricity purchased from utilities throughout the

United States, thus the data does not include prices of electricity that are not received from the utility companies. Then the average price of electricity in the commercial sector in that year is calculated. The variable represents the average price of electricity for commercial consumers in the United States in the span of one year, expressed in cents (USD) per kilowatt-hour (kWh) of energy.

Industrial Electricity Prices

Industrial electricity prices are believed to be a strong predictor of future sales of electricity to the industrial sector, following the same logic that was discussed with regards to residential and commercial electricity prices. The variable of industrial electricity prices aggregates all prices observed in the United States in one year. Electricity prices calculated based on the price charged for electricity purchased from utilities throughout the United States, thus the data does not include prices of electricity that are not received from the utility companies. Then the average price of electricity in the industrial sector in that year is calculated. The variable represents the average price of electricity for industrial consumers in the United States in the span of one year, expressed in cents (USD) per kilowatt-hour (kWh) of energy.

Total Electricity Prices

Total electricity prices are believed to be a strong predictor of future sales of electricity across all sectors on the aggregate, following the same logic that was discussed with regards to the market segments. The variable of total electricity

prices aggregates all prices observed in the United States in one year across residential, commercial, and industrial end users. Electricity prices calculated based on the price charged for electricity purchased from utilities throughout the United States, thus the data does not include prices of electricity that are not received from the utility companies. Then the average price of electricity in the United States in that year is calculated. The variable represents the average price of electricity in the United States in the span of one year, expressed in cents (USD) per kilowatt-hour (kWh) of energy.

Trends in Energy Consumer and Price

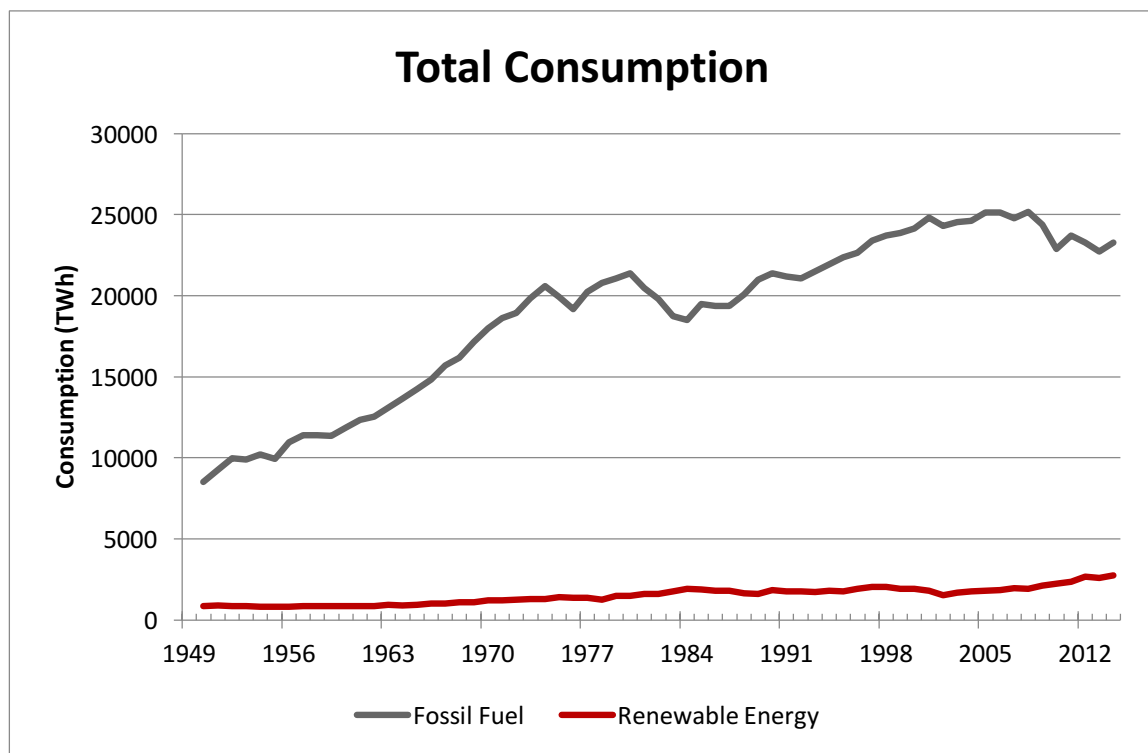
Time Frame

Data utilized to create the predictive models covers the span of 1990-2014 to include as many data points as possible without introducing large unnecessary variables that could create a bias in the data, such as the introduction of nuclear energy or wars in the 20th century. The increased number of data points, when looking at annual statistics, creates a stronger analysis. The lower boundary of this time frame eliminates many of the influences of nuclear energy generation. Additionally, this boundary helps to remove extenuating circumstances that may have effected and biased the data, such as wars and financial crises. Most of the advances in renewable energy occurred after the turn of the 21st century, thus many of the trends spotted in the data correspond to the innovation in the renewable energy sector. Throughout the period of 2000 through the present, the price of a unit of energy from renewable energy generation greatly decreased (Lins). A decrease in the cost per unit of energy played a large role in the increased consumption seen throughout this time period (Lins). Even though the majority of the increases in renewable energy generation and consumption occurred after the world entered into the new millennium, the data utilized throughout this research includes the decade immediately preceding the turn of the millennium. These years were included not only to take into account the need for more observations to strengthen the model, but also to account for the early stages of the renewable energy. The time frame of 1990-2014 encompasses the life cycle of most renewable

energy sources examined in the scope of this analysis and provides enough observations to create a model with greater accuracy.

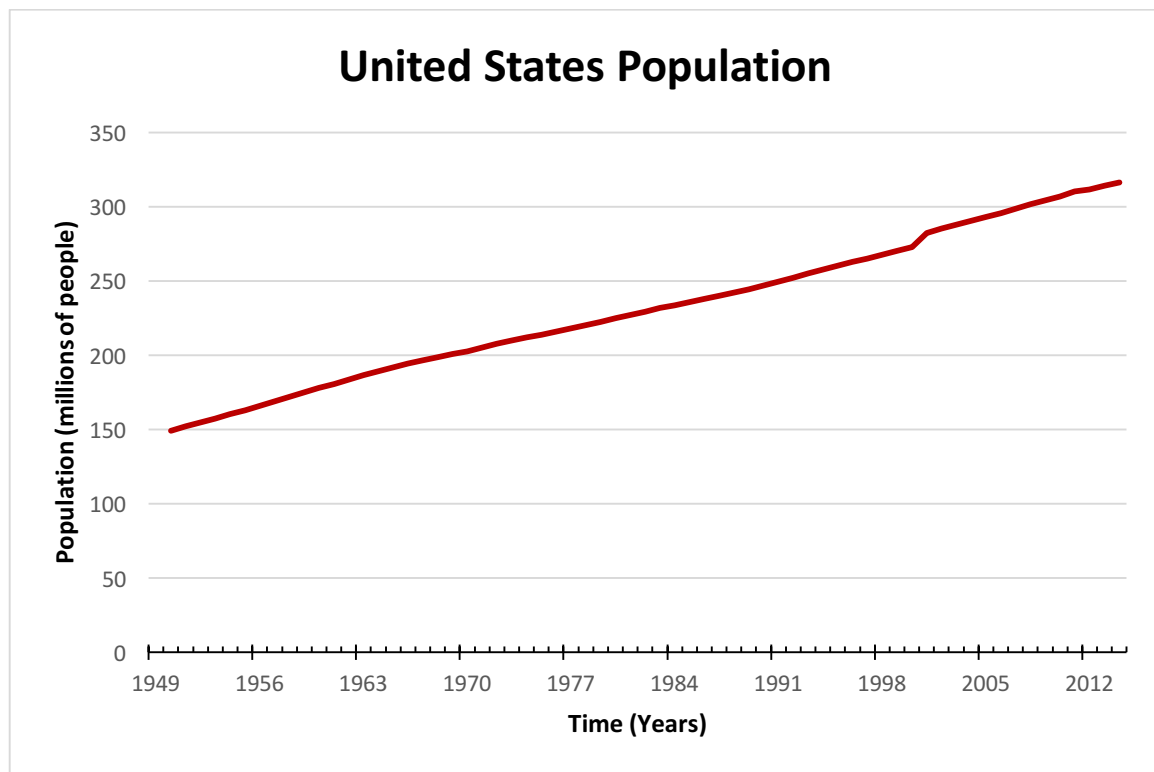
Over the period of 1990-2014, numerous trends emerged that reflect potential future hardships for the utilities sector. Throughout the past few decades, there has been an upward trend in consumption of energy created both by fossil fuels and renewable sources. Since 2000, however, the rate at which fossil fuel energy consumption is increasing has lessened and the consumption of energy from fossil fuels seems to have begun to plateau. On the other hand, renewable consumption, which throughout time has remained relatively constant, has begun to increase. Figure 1 shows the total consumption of fossil fuel and renewable energy over the period 1949-2014.

Figure 1: Total Consumption by Energy Source



In addition to the increase in total consumption of both types of energy source, population in the United States has also increased over the period of 1949-2014 at a steady pace. The annual increase in population in the United States is depicted in Figure 2.

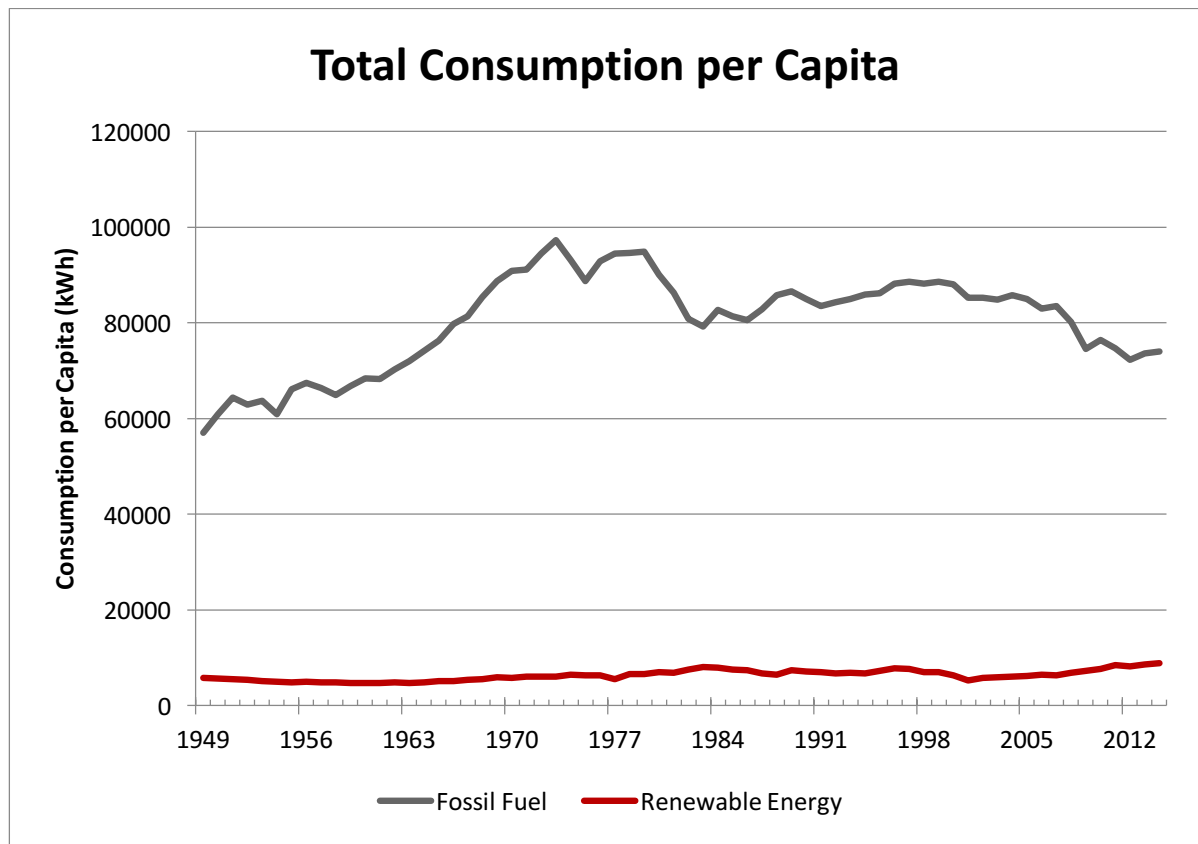
Figure 2: U.S. Population from 1949-2014



After normalizing the total annual consumption of fossil fuels and renewable energy to population, the trends begin to transform. Total fossil fuel consumption per capita charted from 1949-2014 shows an upward trend in consumption until 1980, when the fossil fuel consumption per capita begins to exhibit a stark downward

trend. In terms of renewable energy consumption, renewables do not start to tick upward from remaining constant until about 2000, when renewable energy sources begin to gain traction. Figure 3 shows the trends in fossil fuel and renewable energy consumption after normalization for population growth in the United States.

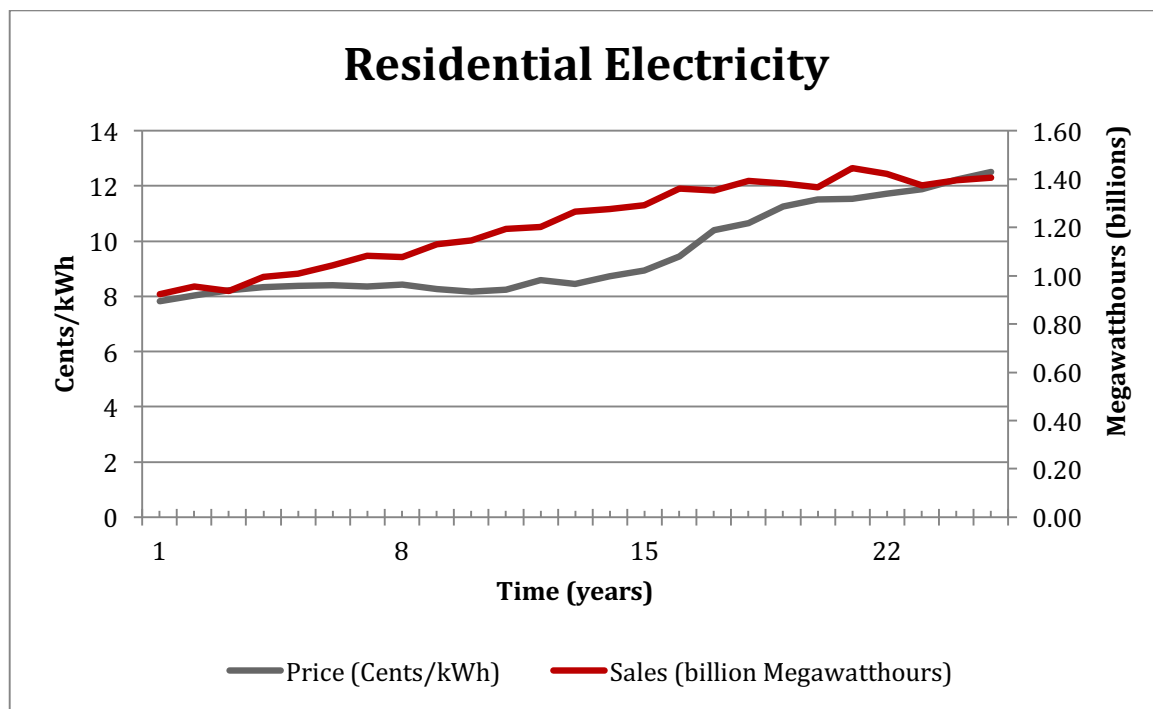
Figure 3: Total Consumption per Capita by Energy Source



In addition to visible trends in consumption of fossil fuel and renewable energy, trends in pricing data emerge as well. Over the period of 1990-2014, there was an overall upward trend in the price of electricity to all sectors of the nation (residential, commercial, industrial, and transportation), but the largest increase is

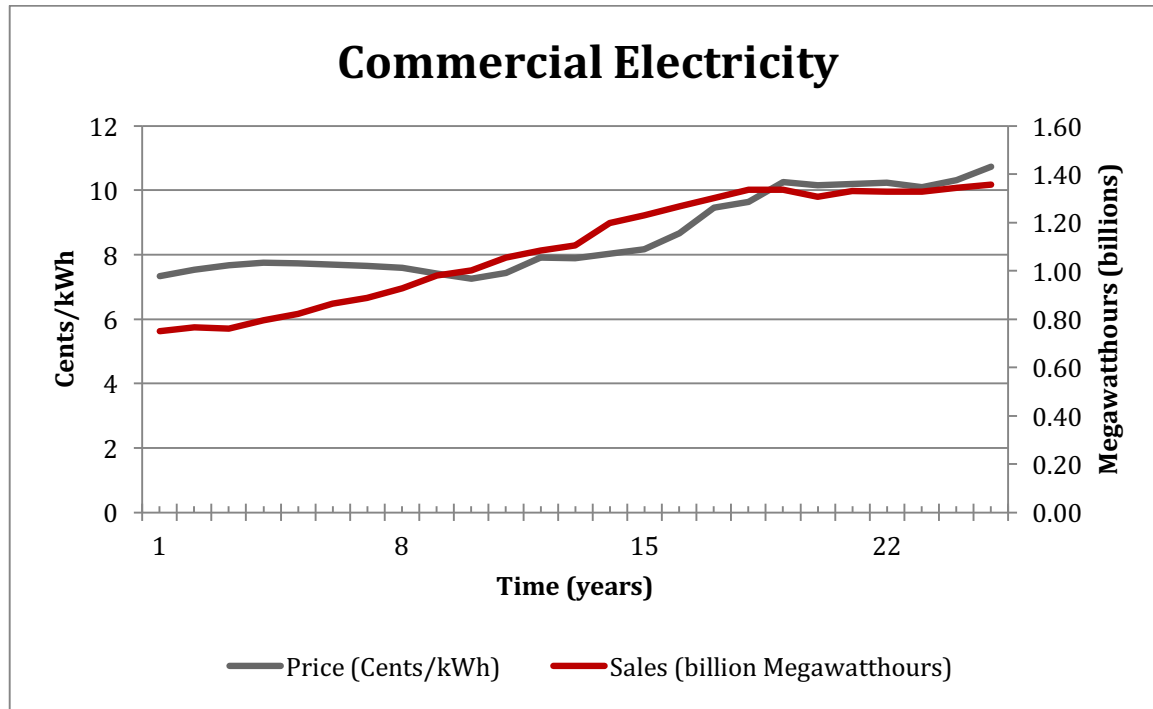
present in the residential sector. From 1990-2000, the price of electricity to residential customers minimally increased, but from 2000 through the present, the price of electricity to a residential end customer has rapidly increased. In 2000, the average price of electricity in the residential sector was about 8.24¢ per kilowatt-hour. By 2014, the price of electricity to a residential customer had reached 12.5¢ per kilowatt-hour. Over the same timeframe as the upward trend in pricing, there is an upward trend in electricity sales, measured in megawatthours, to the residential sector. The increase in this trend remains relatively constant from 1990 through about 2008 when the trend begins to flatten out. From 2008 until 2014, electricity sales growth to the residential sector remains relatively flat. Figure 4 displays the upward trend in pricing of electricity to residential end users as well as the trends in sales to the residential sector.

Figure 4: Residential Electricity Prices and Sales from 1990-2014



Though less increase than the residential sector, the commercial sector has experienced increased electricity prices, from about 7.4 cents per kilowatt-hour (kWh) in 2000 to about 10.2 cents per kilowatt-hour (kWh) in 2008. From 1990 through 2000, electricity pricing to the commercial sector did not experience much increase. However, from 2000 through 2008, the sector saw a steady increase in pricing year over year. This upward trend flattened after 2008, with pricing increasing at a drastically slower pace. Over the same time horizon, an upward trend has appeared in sales of electricity to the commercial end user. From 1990 through 2007, there is a relatively constant positive growth rate in electricity sales to this segment of the market. From 2007 through 2014, however, there was a decline in growth to the point of little to no sales growth year over year to the commercial sector in the electricity market. See Figure 5 for a depiction of the upward trend in pricing of electricity to commercial end users as well as the trends in sales to the commercial sector.

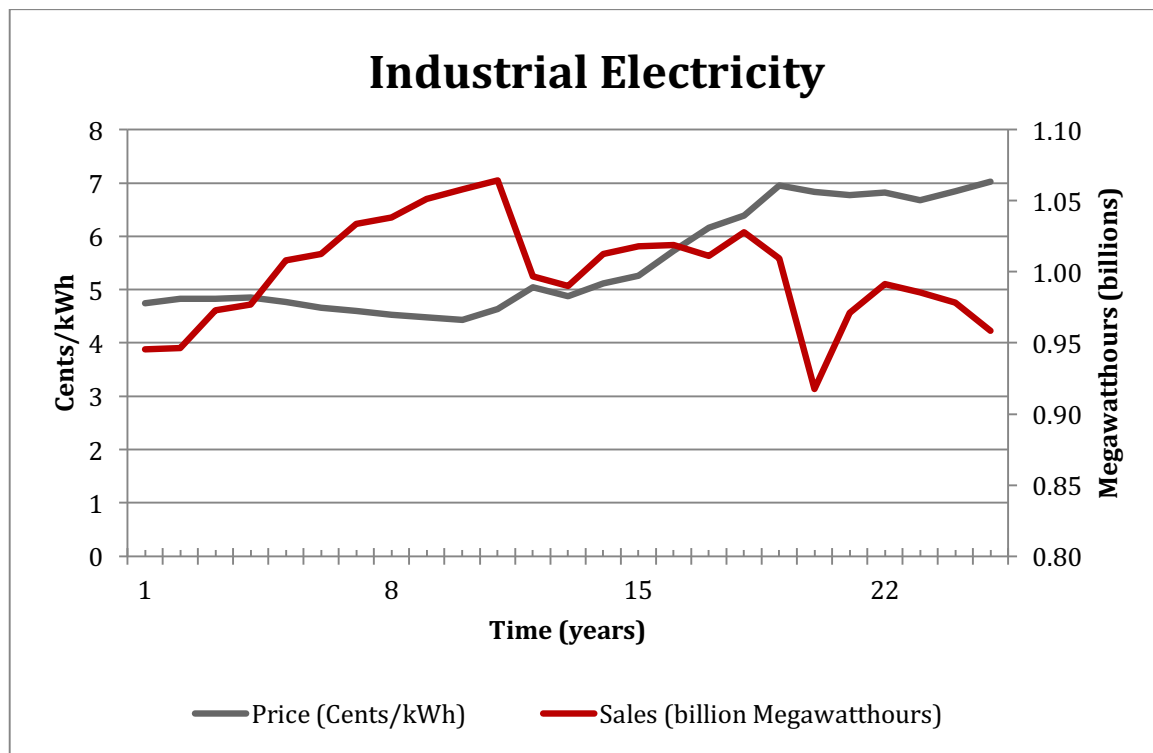
Figure 5: Commercial Electricity Prices and Sales from 1990-2014



Over the period of 1990-2014, the industrial sector has seen similar pricing trends compared to the residential and commercial sectors. However, there are major differences present in the trends that appear in electricity sales to the industrial sector end user. Overall, throughout this time frame, there has been an upward trend present in the electricity prices to the industrial sector. From 1990 through 2000, the price of electricity to the industrial sector slightly declined from 4.74cents per kilowatt-hour (kWh) to 4.43 cents per kilowatt-hour (kWh). In the period 2000 through 2008, there is a constant upward trend in the pricing of electricity to this sector, with the price increasing from 4.43 cents per kilowatt-hour (kWh) in 2000 to 6.96 cents per kilowatt-hour (kWh) in 2008. After 2008, the upward trend flattens off to a period of relatively no change in the price to the industrial sector. In terms of

sales to the industrial sector, two distinct trends have formed over the time horizon in question. From 1990 through 2000, there is a stark upward trend in the sales of electricity to the industrial end user. However, in 2000, the trend shifted to a downward trend that has maintained through 2014. In addition, there was a large negative spike in sales of electricity to the industrial sector in 2009. See Figure 6 for a depiction of the trends in pricing and sales of electricity to the industrial sector customer.

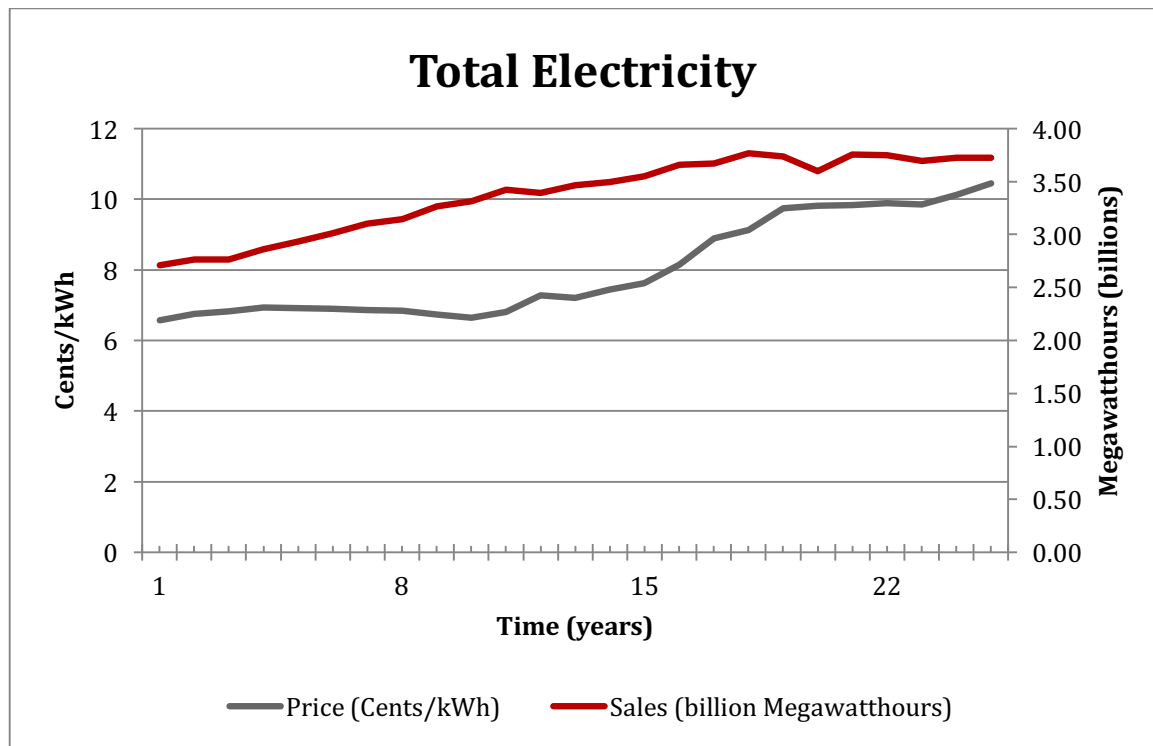
Figure 6: Industrial Electricity Prices and Sales from 1990-2014



As for the total of all sector that receive electricity from utility companies, pricing and sales trends have formed. Overall, in the period of 1990-2014, there has been an upward trend in electricity prices, with the majority of the increase occurring

between 1999 and 2008. Before and after that period, there was relatively no change in the price of electricity aggregated across all sectors. In terms of the sales of electricity, there has been an overall increase over the same period. However, in 2008, the trend flattened to a point of little to no sales growth year over year. Figure 7 shows the overall trends in pricing and sales to the aggregate of all sectors that receive electricity from the utilities sector.

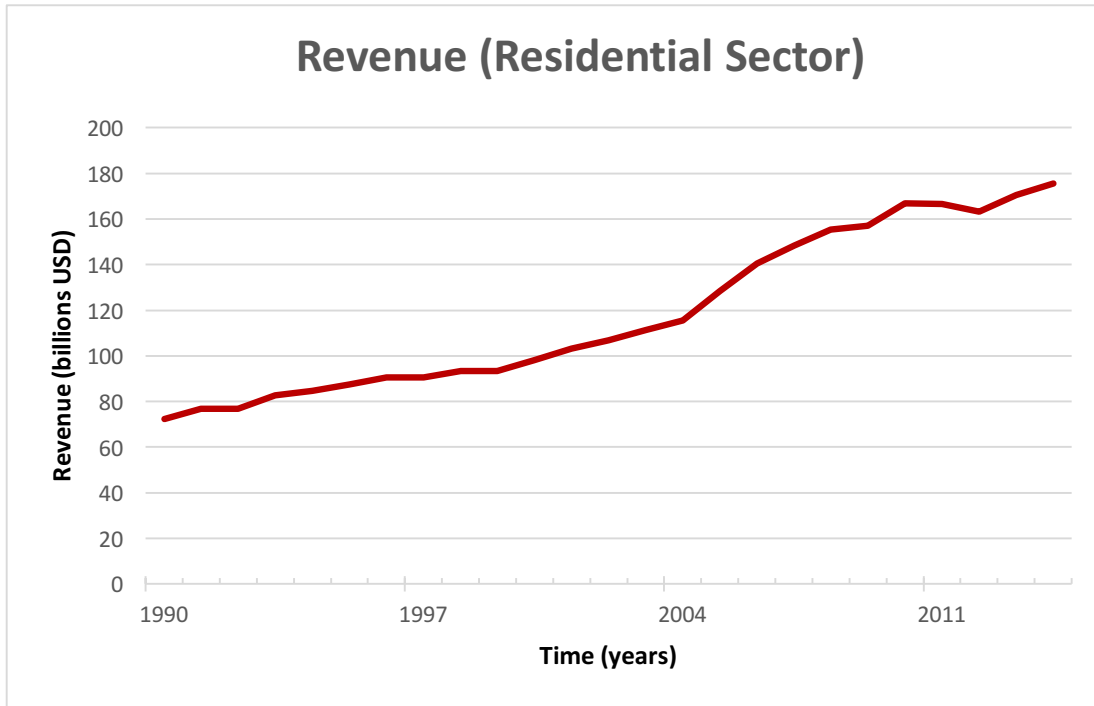
Figure 7: Total Electricity Prices and Sales from 1990-2014



Revenues generated from the residential sector have also experienced an upward trend over the period of 1990-2014. The upward trend greatly slowed, though, from 2006 to the present, suggesting that an external factor is affecting the ability of the

utilities industry to maintain revenue growth. The upward trend in the revenue of utilities in the residential sector is depicted in Figure 8.

Figure 8: Residential Sector Revenue from 1990-2014



Methodology

Multiple linear regression models were created to provide a predictive model to examine the industry environment and any alterations to the current environment. In addition, the models were created to enable analysis of the price sensitivity of different end user segments of the energy market as well as the aggregate market.

Predictive Model

The purpose of the model is to forecast the future landscape of the industry and enable greater analysis as to whether the utilities industry is in need of restructuring so as to maintain current levels of profitability in a changing energy environment. A multiple linear regression model was created to predict the effect that the following factors would have, if any, on the dependent variable.

Dependent variable:

- Consumption of energy generated through fossil fuel sources per capita (kWh)

Predictive variables in the model:

- Renewable energy consumption per capita (kWh)
- Electricity prices for United States (cents/kWh)

The model would incorporate data from each of the three variables over the time frame of 1990-2014, thus using historical data to create a model that if found significant, would be able to predict the future changes in the per capita consumption of fossil fuels. Because much of the energy generated by the utilities

sector originates as fossil fuels, changes in the amount of fossil fuels that are consumed may show provide insights as to whether utilities should shift to producing more energy from renewable sources. Factors would be accepted as significant if the p-value of the coefficient was stronger than a significance level of 0.05. Should the p-value prove to be greater than 0.05, the predictor would be considered insignificant, thus not a strong predictor of profits for the utilities industry.

Analysis of Price Sensitivity

The purpose of the analysis, with regard to price sensitivity, is to determine whether electricity price fluctuations have an effect on the quantity of electricity that is consumed by the end user. The goal of this analysis and the models that this analysis entails is to determine whether a price increase to the end user would cause a change in the total amount of electricity that is consumed. The analysis examines price sensitivity of three different end user segments of the market: residential end user, commercial end user, and industrial end user. In addition, the analysis looks into the price sensitivity of end users in the United States, aggregated across all end user segments of the market. Four multiple linear regression models were created to predict the effect that the following factors would have, if any, on the dependent variable.

Model 1:

Dependent Variable:

- Electricity sales to the residential end user in the United States (MWh)

Independent Variable:

- Electricity price to the residential end user in the United States (MWh)

Model 2:

Dependent Variable:

- Electricity sales to the commercial end user in the United States (MWh)

Independent Variable:

- Electricity price to the commercial end user in the United States (MWh)

Model 3:

Dependent Variable:

- Electricity sales to the industrial end user in the United States (MWh)

Independent Variable:

- Electricity price to the industrial end user in the United States (MWh)

Model 4:

Dependent Variable:

- Electricity sales to the end user in the United States (MWh)

Independent Variable:

- Electricity price to the end user in the United States (MWh)

The models utilize electricity pricing and sales data over the time frame of 1990-2014, thus using historical data to create models that would address the price sensitivity of different end users of electricity delivered by utility companies. End user segments found to be price sensitive could react to rising electricity prices by seeking alternate sources of energy other than that provided by a utility company. Factors would be accepted as significant if the p-value of the coefficient was stronger than a significance level of 0.05. Should the p-value prove to be greater than 0.05, the predictor would be considered insignificant, thus not a strong predictor in the model.

Assumptions

A number of assumptions were made when constructing the multiple linear regression models previously discussed. The assumptions applied to the analyses are as follow:

- Profit margins of the utilities sector, on average, remain the same or close to the same throughout time
- Pricing aggregated across all market segments is a good predictor of the industry outlook (in relation to the predictive model, but not the analysis of price sensitivity)
- All geographical regions of the United States utilize energy in the same manor and that there is no variation across the differing regional sectors

- The market in which the utility company is the consumer and the market where the utility company is the supplier are mutually exclusive
- Fossil fuel consumption per capita is an adequate proxy for the profits of the utilities sector
- Fossil fuel sources and renewable energy sources are substitutes at a ratio of one-to-one
- Renewable energy consumption and electricity pricing across all sectors are the only factors necessary to predict changes in fossil fuel consumption per capita
- Sector (residential, commercial, and industrial) or aggregate electricity price is the only factor necessary to predict the sales in the corresponding sector, thus determining the price sensitivity
- Regulation does not have an effect on the actions of the end user and the utility sector

On average, the utilities sector is believed to react to market influences in a manner that would result in net profit margins remaining the same. In order to maintain a singular profit margin year over year, it is expected that the utilities sector will react by fluctuating prices to offset operating and management costs to the company. This assumption was created to establish the belief that declined sales from a decrease in consumption of electricity from utilities will be offset by a corresponding increase in price to bring revenues and profits to a level that maintains consistency year over year.

The second assumption that was made assumes that total pricing, aggregated across all sectors, is a good indicator of the industry's outlook. It is believed that all sectors (residential, commercial, and industrial) will eventually respond in the same manner to changes in price of electricity. Thus, total pricing will capture the same sentiment as each individual market segment. Additionally, total price across sectors is believed to be the best variable for the predictive model as fossil fuel consumption per capita and renewable energy consumption per capita are both aggregated across all sector. To maintain consistency across variables in the model, total price of electricity as an average across all market segments was assumed to be a strong predictor of fossil fuel consumption per capita.

The third assumption adopts the idea that all states in the country consume and utilize energy in the same manor. All data that was applied to the model was collected at the aggregate level. It is assumed that on average, all variations in energy consumption offset each other, thus making the aggregate figures accurate in predicting the profitability of the utilities sector. In effect, the postulation assumes that if one segment of the United States uses more energy than average, another section of the United States uses an equal magnitude of energy less than the average.

The fourth assumption states that the market in which the utility company is the consumer of fossil fuels is mutually exclusive of the market in which the utility company is the supplier of electricity to the end user. The assumption was formed with the belief that the two markets would not overlap, thus utility companies would not be the end user of the electricity that is generated.

The fifth assumption establishes the belief that fossil fuel consumption per capita is a good proxy for the profits of the utilities sector. In the current structure of the utilities sector, much of the raw materials that are used to generate electricity are fossil fuels. Thus, changes in the per capita consumption of fossil fuel would result in corresponding changes to the consumption of electricity from utility companies. Changes in consumption of electricity from the utility companies will have a direct relation to the revenue and profits that the utilities sector is able to realize. Renewable energy becoming a presence and taking market share from fossil fuels at the turn of the millennium. From the period of 1990-2000, before the increased presence of renewable energies, the correlation between fossil fuel consumption per capita and revenues to the utilities sector was 0.89, thus there is a strong positive correlation between the per capita consumption of fossil fuel and the revenue realized by utilities across the United States. Changes to top line of the income statement of a company have a direct relation to the bottom line, profit, of a company. Thus, per capita consumption of fossil fuels is assumed to have a direct correlation to the profits of the utilities sector in the United States. Because of these relationships, the assumption that fossil fuel consumption per capita is an acceptable proxy for utility sector profits was established.

The sixth assumption for the purposes of these analyses is that fossil fuels and sources of renewable energy are direct substitutes in the generation of electricity. It is assumed that electricity generated from fossil fuels and electricity generated from renewable energy are equal in quality and functionality. Thus, should a customer switch from electricity generated by means fossil fuels to

electricity generated from renewable energy sources, no differentiation would be noticed. Electricity from either source could be used interchangeably without the end user being able to differentiate between the two sources. Therefore, this assumption eliminates the influences of qualitative functionality from a consumer's decision as to whether to receive electricity from the utility company or to generate electricity from renewable sources.

The seventh assumption states that renewable energy consumption per capita and electricity price aggregated to the whole United States, across all sectors, are the only and most important factors in predicting fossil fuel consumption per capita in the same year. It is assumed that the variation in fossil fuel consumption per capita is dependent upon the amount of renewable energy that is consumed per capita and the price of electricity to the end user. All other factors are less important and thus are captured by the error term in the predictive model.

The eighth assumption is that electricity pricing to each sector or to the entire United States is the only and most important predictor in the amount of electricity, sales, that will be consumed by the end user. For the purposes of the determining the price sensitivity in this analysis, electricity price is the only predictor necessary to determine the amount of sales in the same year. All other factors are assumed to be less important and are thus captured by the error terms in the analyses.

For the creation and purposes of the models in this analysis, the last assumption states that regulation is not considered by the end user or the utilities sector. Thus, when deciding electricity price adjustments or what source of energy

to utilize, the utility companies do not need to take into account the effects that regulation could play in the decision. In addition, when end users are determining whether to receive electricity from the utility company or to generate their own electricity, they do not account for the restrictions placed on the industry by federal and state regulation. In summary, the assumption states that players in this industry would make the same choices in an industry with regulation as they would in the same industry with no regulation. Finally, regulation would not have any influence on the price sensitivity of the end user in any of the sectors of the United States industry.

Predictions

H1

The premise of this research centers on the idea that profits of the utilities sector are decreasing and will continue to decrease in the current outlook of the energy industry. It is assumed that, with the current structure of many utility companies (generating most of their energy from fossil fuels), fossil fuel consumption per capita is a good proxy for profits to the utilities sector. It is hypothesized that fossil fuel consumption will continue to decrease as new technologies are introduced to the market that do not use fossil fuel as the primary source of energy generation. There will be an increase in the consumption of energy from renewable sources, such as wind and solar, while fossil fuel consumption will decline, to maintain the current levels of electricity consumption. Thus, the total consumption will remain constant, but the source of the energy will shift away from fossil fuels and toward renewable energy.

In addition, it is hypothesized that energy prices will continue to increase, as the utilities sector attempts to counteract the loss in revenues to renewable energy. With the increase in electricity prices, it is predicted that fossil fuel consumption will decrease as end users search for cheaper alternatives to electricity from utility companies, which is, currently, largely generated from fossil fuels. In order to maintain current profit levels, utilities will raise prices, with some segments of the market seeing greater increases in price.

In terms of the model, it is expected that there is a negative correlation between the consumption of fossil fuel per capita and the consumption of renewable

energy per capita. Additionally, it is expected that there is a negative correlation between the electricity price to end-user and fossil fuel consumption per capita. Annual consumption per capita of renewable energy and electricity prices to end-users are hypothesized to be significant predictors of the annual consumption of fossil fuels per capita, aggregated across the entire United States.

H2

The analysis examines the price sensitivity of electricity consumers in the residential, commercial, and industrial sectors as well as the price sensitivity of all end users aggregated across all market segments. It is hypothesized that price and sales will be negatively correlated. Thus, as the price increases in any of the segments or in the total market, then there will be a corresponding decrease in the amount of electricity that is consumed as the end user will search for a cheaper means of receiving electricity. This search for cheaper means of electricity could consist of utilizing more efficient products that reduce electricity consumption or could potentially be the exit of some as end users of the electricity generated by utility companies, as these customers switch to individual generation through renewable technologies. However, it is also hypothesized that large decreases in sales of electricity would not result from every price increase because of the switching costs involved to the end user. In switching, the customer would need to make a large investment upfront. Thus, it is believed that price increases will lead to a decrease in sales, but at a slower pace than the price increase.

In terms of the models, it is expected that all segments and the aggregated model will see a decrease in the sales of electricity as the price of electricity increases. However, it is also hypothesized that the residential sector will be the most price sensitive as the commercial and industrial sector consists of large customers that have greater flexibility, both in terms of power and finances, to act upon increases of price. With this knowledge, it is believed that the utility companies would be less likely to increase prices in as great a magnitude to the commercial and industrial sectors as these customers retain greater power than customers of the residential sector.

Results

Predictive Model

Multiple linear regression was utilized to create a model used to predict fossil fuel consumption per capita (measured in kWh) from renewable energy consumption per capita (measured in kWh) and electricity price to the end-user in the United States (measured in cents/kWh). The results of this model elaborate upon the trends noticed in Figure 3. The model was manipulated by taking the logarithm of the dependent variable and all independent variables to allow for interpretation of the model in terms of percentage change. Running the regression, a model was generated, based on a sample of 25 observations, which proves to have an acceptable significance for both predictors. Renewable energy consumption per capita and electricity prices to residential end-user were all found to be significant predictors to the 0.05 significance level. The model, consisting of the two predictors, was able to account for 86 percent of the variance ($R^2=0.859$, $N=25$). Rudimentary descriptive statistics and predictor coefficients are found in Table 1.

Table 1: Predictive Model Multiple Linear Regression Output

Predictive Model Regression Results	
	<i>Dependent variable:</i>
	log (Fossil Fuel Consumption)
log (Renewable Energy Consumption)	-0.116** (0.050)
log (Total Electricity Price)	-0.394*** (0.095)
year	0.002 (0.002)
Constant	8.910** (4.082)
Observations	25
R ²	0.859
Adjusted R ²	0.839
Residual Std. Error	0.026 (df = 21)
F Statistic	42.555*** (df = 3; 21)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01

Analysis of Price Sensitivity

Multiple linear regression was utilized to create models used to examine the price sensitivity of end users in different market segments (residential, commercial, and industrial) and across the aggregate United States. Each of the four models utilizes electricity price (measured in cents/kWh) for the respective market segment or the aggregate United States to predict the electricity sales (measured in

MWh) in the corresponding market segment or the aggregated United States. The results of this model elaborate upon the trends noticed in Figures 4-7. The model was manipulated by taking the logarithm of the dependent and independent variables to allow for interpretation in terms of percentage change. Each of the four separate regressions was generated based on a sample of 25 observations. Rudimentary descriptive statistics and predictor coefficients for each of the regressions can be found in Tables 2-5.

Table 2: Residential Price Sensitivity Multiple Linear Regression Output

Residential Price Sensitivity Regression Results	
	<i>Dependent variable:</i>
	log (Residential Electricity Sales)
log (Residential Electricity Price)	-0.550 (0.409)
year	0.025*** (0.009)
Constant	-28.459 (17.035)
Observations	26
R ²	0.478
Adjusted R ²	0.432
Residual Std. Error	0.122 (df = 23)
F Statistic	10.522*** (df = 2; 23)
<i>Note:</i> *p<0.1; **p<0.05; ***p<0.01	

Table 3: Commercial Price Sensitivity Multiple Linear Regression Output

Commercial Price Sensitivity Regression Results	
	<i>Dependent variable:</i>
	log (Commercial Electricity Sales)
log (Commercial Electricity Price)	-0.389 (0.487)
year	0.029*** (0.009)
Constant	-36.659** (17.197)
Observations	26
R ²	0.624
Adjusted R ²	0.591
Residual Std. Error	0.140 (df = 23)
F Statistic	19.069*** (df = 2; 23)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01

Table 4: Industrial Price Sensitivity Multiple Linear Regression Output

Industrial Price Sensitivity Regression Results	
	<i>Dependent variable:</i>
	log (Industrial Electricity Sales)
log (Industrial Electricity Price)	-0.189 (0.300)
year	-0.002 (0.007)
Constant	24.477* (13.234)
Observations	26
R ²	0.137
Adjusted R ²	0.062
Residual Std. Error	0.118 (df = 23)
F Statistic	1.831 (df = 2; 23)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01

Table 5: Total Price Sensitivity Multiple Linear Regression Output

Total Price Sensitivity Regression Results	
	<i>Dependent variable:</i>
	log (Total Electricity Sales)
log (Total Electricity Price)	-0.353 (0.398)
year	0.016* (0.009)
Constant	-10.358 (17.366)
Observations	26
R ²	0.272
Adjusted R ²	0.209
Residual Std. Error	0.123 (df = 23)
F Statistic	4.306** (df = 2; 23)
<i>Note:</i>	*p<0.1; **p<0.05; ***p<0.01

Interpretation

By taking the logarithm of each variable, it is possible to predict the elasticity of change in profits in the wake of a change in any of the independent variables. After taking the logarithm of each term, results are interpreted as a percent change. Thus, a one percent increase in renewable energy consumption per capita leads to a 0.116 percent decrease in fossil fuel consumption per capita. Additionally, a one

percent increase in electricity pricing aggregated across all sectors in the United States results in a 0.394 percent decrease in fossil fuel consumption per capita. Thus, fossil fuel consumption per capita is most sensitive to a change in electricity prices aggregated across all sectors, as the coefficient of total electricity price is greatest.

Even though the fossil fuel consumption per capita is affected by an increase in electricity prices, it is unlikely that prices will react extremely. Greatly increased electricity prices to end users could prove to be the driving force that pushes a greater number of households to move toward distributed energy, thus moving away from electricity supplied by the utility sector. However, a one percent increase in electricity prices would not be a great move and would not be a surprise to the industry as utilities attempt to counteract the forces eating into their profits. At 2014 prices, a one percent increase in the price of electricity would equal 0.12 cents per kilowatt-hour. From 1990-2014, the aggregated price of electricity experienced a 58.9 percent increase, thus measurable increases can be expected in the near future. Based on the outputs of the regression models, end-users of electricity across all sectors are price inelastic, thus a large, rapid exodus from the national electric grid is unlikely. However, the coefficients of the price sensitivity regressions were found to be insignificant, thus it cannot be said with certainty that the consumers are price inelastic. Based on the switching costs associated with leaving the grid, it is expected that consumers would be price inelastic in the short-term time horizon.

In terms of the applicability of an increase in the level of consumption in either fossil fuels or renewable energy, a one percent increase is plausible. A one

percent change in utilization, based off of 2014 statistics, is equivalent to the addition or subtraction of 739.5 kWh and 88.4 kWh for fossil fuels and renewable energy, respectively. A one percent change in the consumption of fossil fuels for a household could be the addition of a new refrigerator into the household or the removal of an old refrigerator from the household. A one percent change in renewable energy consumption could be the purchase of a desktop computer with a monitor or the addition of a ceiling fan into the household. Table 6 displays a list of electricity usage per an average household of four people segmented by the type of appliance and age of the appliance. Based off of usage data, it is highly plausible that a one percent increase or decrease in fossil fuel consumption or renewable energy consumption could occur, as predicted in the multiple linear regression model.

Table 6: Electricity Usage by Household Appliance (“Electric Usage Chart”)

APPLIANCE	Monthly Average			Annual Average	
	HOURS IN USE	KWH USED	MONTHS USED	ANNUAL KWH	ANNUAL COST
A/C - Central	125	375	3	1,125	\$158
A/C - Room/Window	100	90	3	270	\$38
Clothes Dryer - Electric	20	75	12	900	\$126
Clothes Dryer - Gas (does not incl. gas use)	23	9	12	108	\$15

Clothes Washer (does not incl. warm/hot water)	30	9	12	108	\$15
Coffee Maker (residential)	30	5	12	60	\$8
Computer - Desktop with Monitor	60	8	12	96	\$13
Computer - Laptop	60	1	12	12	\$2
Dehumidifier	250	200	6	1,200	\$168
Dishwasher - Heat dry	16	13	12	156	\$22
Dishwasher - Air dry	16	8	12	96	\$13
DVD Player	45	2	12	24	\$3
Electric Heat - Baseboard, 10 feet	240	300	5	1500	\$210
Electric Heat - Portable / plug-in	240	360	6	2160	\$302
Engine Block Heater	180	135	4	540	\$76
Fan - Attic	64	24	3	72	\$10
Fan - Bath	15	1	12	12	\$2
Fan - Ceiling (does not incl. lights)	150	12	6	72	\$10

Moving Forward

Alterations of the Data

Numerous alterations to the data could be made that may have a positive effect on the accuracy of the model as a forecasting tool, including less aggregated data across a number of factors. Much of the data that was used to create the first predictive model (refer to Table 1) was aggregated to the national level and across all the sectors. Aggregation at such a high level created difficulty in pin pointing the variables that proved most important. In addition, the data was utilized as a total of the consumption or pricing across all demographics and regions of the United States, thus removing any variations that may arise from these variables. All variation that is caused by different regions of the country was effectively disregarded as data was unable to be found for all chosen predictors across the different regions. In reality though, energy usage in different regions of the country may not equally offset each other. If the regions do not offset one another, then the utilities sector could experience differing effects from changes in fossil fuel consumption per capita, renewable energy consumption per capita, and residential end-user electricity pricing. Ranging effects in the predictor variables implies that there could be a difference in the per capita consumption of fossil fuels depending on the region of the country, resulting in differences in profitability of the utilities sector.

Should differences exist depending on the region of the nation, less aggregated data would allow for a model to be created that would give greater accuracy and be able to predict the changes in fossil fuel consumption per capita in a

given region of the country. Having consumption data that was segmented into different regions or by state would allow for a more flexible model to be implemented. In addition, state or regional level population data would allow for the consumption data to be normalized by means of population.

In addition to less aggregated data, the model could be strengthened with the introduction of data for the price of electricity generated solely from renewable energy. Electricity prices utilized in this analysis were found as an average electricity price charged by numerous utility companies throughout the United States. Thus, the electricity prices utilized were charges for electricity that was generated from mainly fossil fuels, but also some renewable energy, should the utility use renewable energy to generate a portion of its electricity output. Therefore, the model would become more accurate should it be possible to differentiate between the price of electricity that is generated solely from fossil fuels and the price of electricity that is generated solely from renewable energy sources.

Additionally, more insight would be provided to the model if data as to the ratio of fossil fuel consumption to renewable energy consumption by the utility company in the process of electricity generation could be found. This data would provide information as to whether the industry is reacting to trends in fossil fuel consumption and renewable energy consumption.

Another alteration that could be beneficial in increasing the accuracy and applicability of the model would be data that reflects the regulation in the energy and utility industries. Regulation of the industry currently places obstacles in the path of discontinuing receipt of electricity from the utility companies through the

national electric grid. Should data be included that provides insights into the industry regulatory environment, the model could be strengthened as the ability of end user to seek alternate sources of electricity would be taken into account.

There are many variables that likely effect utility companies' decisions, end users of electricity, fossil fuel consumption, renewable energy consumption, electricity prices, and electricity sales that have not been accounted for in the models of this analysis. Introduction of more variables may prove to improve the accuracy of the predictability of these models. However, because of the broadness of the topic and the industry, finding correct variables to include proves to be difficult.

Logical Model

Because of the infinite number of variables that could have an impact on the decisions of utility companies and the end consumer of electricity, an analysis based on regression, may not prove to be the most accurate approach to addressing the future of the changing energy industry. One could, instead of creating multiple linear regressions or other statistical models, create a logical model. Through the creation of a logical model, the actions of the utility company and the end user would be predicted based upon a logical series of events in the industry and the macroeconomy, with the purpose of maximizing consumer utility, consumer cost savings, and utility sector profits. Quantitative analysis would not be applicable in a logical model. Conversely, a logical model would provide a series of cause and effect relationships that would result in explanations of producer and consumer decisions as well as explanations of changes in fossil fuel consumption per capita, renewable

energy consumption per capita, electricity prices to differing sectors, electricity sales to differing sectors, and other variables found to be pertinent to the reasoning of said changes.

Expansion of Time Horizon

The multiple linear regression models were created using data from 1990-2014, which leaves out a large amount of data from previous years of reporting. The past data was discarded in creating the model to only account for the effects of fossil fuel consumption after the first wave of renewable energy consumption. If it were possible to extrapolate the data in a way that would remove biases, such as the introduction of nuclear power, financial crises, and war, then a larger time horizon would provide more observations for the model. A larger time horizon would allow for more degrees of freedom in the model, thus increasing the strength of the model. However, if biases cannot be removed, the data would create a less accurate model that is greatly affected by extenuating circumstances.

Discussion

Increasing electricity generated from renewable energy sources are becoming a viable option to replace electricity received from the utility company, which generates most of its electricity from fossil fuels. As consumers face heightened prices from the utility companies for the electricity that they use, consumers are more likely to leave the grid in search of alternate methods of electricity generation, such as installing solar paneling on their household or constructing a small wind turbine on a property. Additionally, consumer concern for the environmental impacts of fossil fuel consumption will play an increasing role in the switch from fossil fuel generated electricity to electricity generated using renewable sources. Because the utility sector's infrastructure continues to be a majority fossil fuel consuming facilities, utility companies could be in danger of missing the switch to renewables, thus experiencing an exodus of customers. If the utilities sector does not act to change the structure of the energy sourcing, the companies could fall behind the innovation curve and begin to realize financial losses in addition to losses in customer base. Should the losses prove great enough, the utility companies may choose to lessen their maintenance of the national electric grid. Should the national electric grid not be properly maintained, remaining customers of the utility companies could become motivated to leave the grid and find ways to generate their own electricity. Thus, in the most severe case, utilities lose some customers, decide to cut costs by reducing maintenance of the distribution network to the remaining customers, and expedite the exit of their remaining customer base.

However, if the utility sector is able to realize a fundamental shift in the source of energy from fossil fuels to renewable energy, the sector could adjust its structure and hedge against the changing energy environment. Those companies that are able to realize the shift, understand the changing environment, and adapt are predicted to be in a stronger position in the distant future when the impact of renewable energy is noticed on a much greater scale. Thus, utilities that plan to remain operational in the distant future should begin switching and adapting their current infrastructure before the window of innovation has passed. Should the federal government not assist, those companies that miss the window will likely experience decreased profits and eventual cease of operations.

Conclusion

Current trends suggest that there will continue to be growth in the renewable energy sector. In addition, trends in fossil fuel suggest that consumption of fossil fuel will continue to decrease in the future. With the continuation of these trends, the current state of the utilities sector could be threatened. Based upon the multiple linear regression in this analysis, an increase in the consumption of renewable energy, combined with an increase in electricity prices, could lead to a stark drop in fossil fuel consumption per capita and decreased profits to the utilities sector, as fossil fuel consumption is a proxy for profits. To counteract this decline in revenue and profits, utility companies may attempt to further raise electricity prices to end user, but prices can only increase so much before customers will leave and move to a more cost efficient source of energy, such as solar or wind power. Even though consumers in the different segments are believed to be price inelastic, continuously increasing electricity prices will eventually push the price inelastic consumers away from electricity of the utilities sector and toward alternate sources of electricity generation.

Without a change in the structure of the utilities sector, the companies that occupy the sector will increasingly suffer from the changing energy environment. Should their financial suffering become great enough, the utilities sector is likely to begin neglecting the national electric grid, to the point that regulations will allow. To avoid this impending situation, the utilities sector will need to adapt by either cutting costs to the end user or begin larger-scale transitioning into innovative technologies, such as renewable energy, smart grid technologies, and distributed

energy. Should the utilities sector be able to transition into these areas, there is hope that the current utility companies will be able to remain the prominent player in the energy generation and distribution industries.

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Appendix

Table 7: Complete Electricity Usage by Household Appliance (“Electric Usage Chart”)

	Monthly Average			Annual Average	
APPLIANCE	HOURS IN USE	KWH USED	MONTHS USED	ANNUAL KWH	ANNUAL COST
A/C - Central	125	375	3	1,125	\$158
A/C - Room/Window	100	90	3	270	\$38
Clothes Dryer - Electric	20	75	12	900	\$126
Clothes Dryer - Gas (does not incl. gas use)	23	9	12	108	\$15
Clothes Washer (does not incl. warm/hot water)	30	9	12	108	\$15
Coffee Maker (residential)	30	5	12	60	\$8
Computer - Desktop with Monitor	60	8	12	96	\$13
Computer - Laptop	60	1	12	12	\$2
Dehumidifier	250	200	6	1,200	\$168
Dishwasher - Heat dry	16	13	12	156	\$22
Dishwasher - Air dry	16	8	12	96	\$13
DVD Player	45	2	12	24	\$3

Electric Heat - Baseboard, 10 feet	240	300	5	1500	\$210
Electric Heat - Portable / plug-in	240	360	6	2160	\$302
Engine Block Heater	180	135	4	540	\$76
Fan - Attic	64	24	3	72	\$10
Fan - Bath	15	1	12	12	\$2
Fan - Ceiling (does not incl. lights)	150	12	6	72	\$10
APPLIANCE	HOURS IN USE	KWH USED	MTHS USED	ANNUAL KWH	ANNUAL COST
Fan - Table / Box / Floor	71	11	3	33	\$5
Freezer -chest, 18 CF, manual defrost, 20 years old	730	75	12	900	\$126
Freezer - chest, 18 CF, manual defrost, 10 years old	730	51	12	612	\$86
Freezer - chest, 17 CF, manual defrost, new	730	36	12	432	\$60
Freezer - upright, 17 CF, auto defrost, 20 years old	730	112	12	1,344	\$188
Freezer - upright, 17 CF, auto defrost, 10 years old	730	90	12	1,080	\$151

Freezer - upright, 17 CF, auto defrost, new	730	57	12	684	\$96
Freezer - upright, 17 CF, manual defrost, 20 years old	730	76	12	912	\$128
Freezer - upright, 17 CF, manual defrost, 10 years old	730	51	12	612	\$86
Freezer - upright, 17 CF, manual defrost, new	730	40	12	480	\$67
Heating System - Boiler Hot Water Circulators (does not incl. fuel use)	178	48	6	288	\$40
Heating System - Furnace Fan Blower (does not incl. fuel use)	178	152	6	912	\$128
Hot Tub - Indoor (pump & heater)	70	196	12	2,352	\$329
Hot Tub - Outdoor (pump & heater)	128	298	12	3,576	\$501
Lighting - Incandescent, 100 watts	100	10	12	120	\$17
Lighting - CFL, 25 watts	100	1	12	12	\$2
Microwave Oven	8	11	12	132	\$18
Oven Broiler - Electric	4	6	12	72	\$10
APPLIANCE	HOURS IN USE	KWH USED	MTHS USED	ANNUAL KWH	ANNUAL COST

Oven - Electric	8	21	12	252	\$35
Oven - Electric, Self Cleaning Cycle	3	8	1	8	\$1
Range Top - Electric, large cooking surface unit	8	19	12	228	\$32
Range Top - small cooking surface unit	8	10	12	120	\$17
Refrigerator - 18 CF, 20 years old	730	98	12	1,176	\$165
Refrigerator - 18 CF, 10 years old	730	70	12	840	\$118
Refrigerator - 18 CF, new	730	41	12	492	\$69
Refrigerator - 22 CF, side-by-side, 20 years old	730	135	12	1,620	\$227
Refrigerator - 22 CF, side-by-side, 10 years old	730	96	12	1,152	\$161
Refrigerator - 22 CF, side-by-side, new	730	56	12	672	\$94
Satellite Dish / Cable Receiver	730	18	12	216	\$30
Sauna	4	28	12	336	\$47
Swimming Pool - Filter Pump, 1 HP	365	274	4	1,096	\$153

Television - 27 inch, LCD flat screen	150	18	12	216	\$30
Television - 42 inch, Plasma	150	49	12	588	\$82
Television - 15-27 inch, standard	150	18	12	216	\$30
Waterbed	256	96	12	1,152	\$161
Water Cooler/Heater	730	61	12	732	\$102
APPLIANCE	HOURS IN USE	KWH USED	MTHS USED	ANNUAL KWH	ANNUAL COST